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Head and Neck

Morphology, Models and Function

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Since interest by definition, connotes biased self-limitation, the scientific information gained remains incomplete, short of the comprehensiveness to which science in its professed universality aspires. So, how sure can we be that sheer analysis alone does not irretrievably destroy highly relevant data about nature? (Weiss 1967).

Preface

Peter Block in his "The answer to how is yes" tells the anecdote "What do you do when you find yourself in a hole?" The answer is: "The first thing you do is stop digging" (Block 2002). It seems foolish, but if you find yourself in a "hole" in anatomy, you start digging by performing extra preparations around and in the dissection area for identification of more structures. They help to solve your problem, because structures do have a basic topographical relation (see introduction on spatial coherence). Nowadays the question arises: Is anatomical "digging" still valuable for the sciences?

The most frequent question about the value of anatomy is: "Is anatomy ossified as a field of knowledge? Alternatively, is anatomy on the threshold of a renaissance? … Is anatomy education being threatened with extinction? Alternatively, is the teaching of anatomy continually evolving and reinventing itself?" (Eizenberg 2015). In other words, if science can be compared to a crossword puzzle does anatomy still have blank spaces? The answer is simple if one is involved in post-doctoral courses. You notice the lack of anatomical knowledge in medical and paramedical professions, mostly covered by arrogance or senseless nomenclature. Anatomy and neuroanatomy are an absolute need in both research and education (see, e.g. Chaps. 3 and 4 on development). Two research fields illustrate this: in the anatomical vascular research the concept of angiosomes (Taylor and Palmer 1987) and in neuroanatomy the cerebellar concept of longitudinal zones and compartments (Voogd et al. 1996; for overview see Ruigrok 2011). Both anatomical concepts totally renewed research in their fields. By the way, there is no Nobel Prize for Anatomy and only two neuroanatomists ever received a Nobel Prize, the one for physiology or medicine: Camillo Golgi and Santiago Ramon y Cajal in 1906. Seemingly valuable anatomical research does not earn a prize. There are also fields where anatomy loses track of developments. Chapter 7 gives an example concerning automated face recognition that no longer needs any anatomical information, quantitative or even qualitative.

In our current approach of anatomy or neuroanatomy, we prefer to look at the micro- and nano-levels as expressed in cell biology and molecular biology. In fact, we gain precision but lose perspective. Looking at the macrolevel of nature, to the properties of a group, like in histology or (neuro)anatomy, knowledge of unexpected properties of groups or populations can lead to study at the microlevel. For example, storage of fat molecules—think of cholesterol (see Sect. 14.2.1 on atherosclerosis)—occurs in the so-called smectic state (well-defined concentric layers of lipid molecules). If the substratum provides structure, all new fat molecules will follow these structural predestined constructions. If such an escorting substratum is missing, fat molecules will group in micels. They are still ordered structural patterns that are determined by the properties of the fat molecules. Although regularity and patterning of the micels are clearly recognizable and repeatable, each of the subparts are unique and no microsample is equal. The same holds for, e.g., glia cells: each glia cell is unique and the general pattern is the same everywhere in the same nucleus (see Weiss 1967).

Marani's introduction of a course on "kaakchirurgie" (oral and maxillo-facial surgery; 1988/1989/1990) together with Kostas Lekkas led to a series of clinical postdoctoral courses in the Leiden Academic Hospital (later named Leiden University Medical Centre, LUMC) on Head and Neck surgery, arm and hand surgery, leg surgery, pelvic surgery (by Marco de Ruiter, anatomy department) and craniotomy, organized by several clinical departments, together with Marani's neuroanatomical group. It started with Marani's regular courses in gross anatomy for medical and biomedical students in 1985/1986. At the end of each session, a clinician was invited to explain the importance of that days preparations to the students in the dissection room. It brought an interplay between the student interested in clinics and the clinician reviving and discovering anatomy. The clinician consequently wanted anatomical dissections to extend his knowledge often due to newly developed surgical techniques or to teach his younger colleagues in order to raise the quality of the department.

New techniques are developed by universities and firms. At the LUMC, a so-called HoloLens is used to project 3D pictures on the cadaver. It is called mixed reality and is also capable of instructing movements (LUMC 2017). Anatomage Table (info@anatomage.com, USA) or Sectra Table (www.3bscientific.com, Germany) are digital display equipments that react on the students' questions or make identification of structures possible. Navigator (Anatomage, USA) is a real-time volumetric inner anatomy tool with tracking stylus, visualizing cross sections or 3D anatomy. Digitizing and programming anatomical data goes rapidly and is effective in education.

Anatomy contains an enormous amount of data. Not all figures in this book are solely illustrations to the text. Some are a means of reducing text by the compilation of anatomical facts, e.g. Fig. 8.8 all blood vessels of the eyeball with the ophthalmoscopic view of the retina or subdivisions of the neck muscles Fig. 14.1. These illustrations allow the narrative to flow without too many interruptions.

Telling the story necessarily draws on ancient history, but also information from the recent past. It is interesting to note that various anatomical descriptions passed on from the Middle Ages and Renaissance are still valuable (see Historical panoramas in The Pelvis, Marani and Koch 2014). For example, ideas about symmetry in picturing of the human body have hardly changed, and the essence of topographic anatomy, picturing the exterior of the body for the projections of the different organs onto the surface, is still unaltered. "History determines our insight into the constituents and their interconnected functions in the human body. This perspective still defines our clinical approach in diagnostics and therapy" (Marani and Koch 2014). While it is a sad story with rather depressing results for the pelvis and its organs, in Head and Neck studies the results are far more optimistic, although in some areas there is a clear lack of knowledge and sometimes charlatans practice the (pseudo-)science.

"The sensory experience obtained by the anatomist during a dissection needs to be recorded by a medium outside his/her mind, in order to become accessible knowledge that can be theorized, discussed and disseminated" (Zwijnenberg 2004). It can be a drawing, painting, photograph and, of course, a model. Modelling arose also from the production of automatons, androids and robots. In arts, this anatomical, mechanistic view was expressed in engravings, but also vulgarized, e.g. for Head and Neck by Louis Poyet (1846–1913; Fig. 1). Modelling of the Head and Neck structures together with finite element methods has brought enormous progress in the understanding of functional morphology (think of applications in

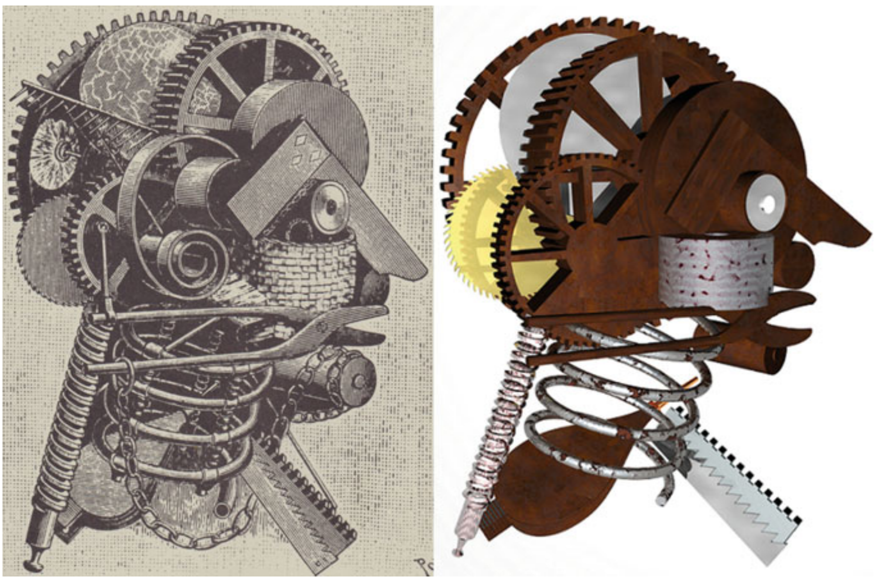

Fig. 1 Three-dimensional remake of "The Head and Neck of an Inventor", wood carving by Louis Poyet (1846–1913). *courtesy* E. Baas

robotics). In neuroanatomy, the cortico-basal ganglia thalamo-cortical map has been the basis for the study of Parkinson's disease. Direct and indirect pathways are discerned. The value of the subthalamic nucleus models for the verification of these neuroanatomical maps are indispensable and clearly contribute to the validation of deep brain stimulation (Heida et al. 2008) and thus to the quality of the motor behaviour of the body, including Head and Neck. Moreover, the direct electric stimulation of Head and Neck structures is evidently increasing: vagus stimulation in epilepsy, auditory stimulation for deafness, hypoglossus stimulation in obstructive sleep apnoea and Neuromodulation of the cervical dorsal root ganglion for arm pain, to give a few examples (see the journal *Neuromodulation* for more examples). Electric stimulation for monitoring is used for cranial nerves VIII and VII during operations. Tinnitus is the perception of sound in the absence of an external source. Vestibular–cochlear nerve stimulation should suppress this phantom hearing. For all these neurostimulation methods, new and additional anatomical data need to be gathered, as exemplified in the literature (see, e.g. Gharb et al. 2015 and for more examples see Marani and Lakke 2012) and modelling is in most cases a necessary prerequisite for human application. The scientists who collect these data can be grouped in lumpers and splitters. As an example, consider the types of the ansa cervicalis: 4 main groups by the older anatomists, 7 main groups by clinicians and 7 main groups with 21 subgroups by clinical anatomists. This last division clearly defeats the purpose (see Chap. 14), and it does not lead to basic concepts. It reminds us of Phil Patton's (1996) "Top this: Coffee-cup Lids". His description and study of the various types of plastic coffee-cup lids that piled up in his car (the data gathering) and finally the needed search for the original "Solo Traveler" coffee-cup lid patent (the basic concept of the lid).

This book on Head and Neck is not an anatomical handbook, you can find better and more complete ones. Instead it tries to show unexpected approaches and to give other basic views besides the classical ones. Head and Neck is written for the well-educated layman, scientist and clinician. It is for the reader to decide whether the authors succeeded.

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Enschede, The Netherlands Enrico Marani
April 2018 Ciska Heida

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Contents

Chapter 1
Introduction

The compartments of Head and Neck do contain spatial and structural relations. Paired and unpaired structures are present that are explained by processes involved in differentiation, morphogenesis and growth. The concept of spatial coherence will be used to elucidate these Head and Neck relations throughout this book. Attention is paid in this introductory chapter to personality, to Roman rhetoric and to head transplantation.

1.1 Compartments of Head and Neck

You cannot live without a head. Before the rifle, executions were performed by decapitation or by hanging. In both cases, main passage ways of the neck were destroyed or blocked.

"The only son of an artificer of six or seven years of age, went into the shop of a neighbour, who was his father acquaintance; in playing with the child, he put one of his hands under his chin and the other behind his head, and lifting him up into the air, told him, *he would shew him his Grandfather*, a mean and vulgar way of speaking. The child was no sooner lifted of the ground than he grew refractory, dislocated his head and died that instant. His father (who was immediately told of it) being transported with passion, ran after his neighbour, and not being able to overtake him threw after him a Saddler's Hammer, which he had in his hand; the sharp end whereof pierced what is called the pit of the neck, and cutting all the muscles, and penetrating the space between the first and second vertebra of the neck, cut the marrow of the spine, whereof he expired the same hour. Thus these two deaths happened almost after the same manner.

This way of playing with children is but too common with the vulgar, because they don't know the danger to which they expose them. Perhaps also, the child had not died if he had not been so refractory: for I do not at all doubt but his struggling was one of the principal causes of the dislocation of his head.

E. Marani and C. Heida, *Head and Neck*,
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T'is observed, in almost all hanged persons that the first vertebra of the neck is entirely separated from the second. It may be even the greatest and most proper cause of their deaths. This observation makes me believe the head and first vertebra of the neck are very difficult to be parted, and that generally when the head is thought to be dislocated t' is nothing else but a luxation of the first vertebra from the second" (Petit 1705, 1726).

Petit's observation is incorrect. Hanging breaks the isthmus of vertebra C2 and as a consequence the pinching off of the myelum occurs. It is called "Hangman's fracture". Moreover, separation of Head and Neck is caused by a head (C_0)–C_1 dislocation. C_1–C_2 connection is maintained, due to the strong ligament connections between C_1–C_2 and the weak C_0–C_1 connection is caused by the occipital condyles.

Besides the upper spinal cord, important pathways for air and food, a number of different structures and functions are incorporated in the Head and Neck of the body: Eye, ear, nose, mouth, the brain and the transition of the skull into the vertebral column that give humans knowledge of their environment by seeing, hearing, smelling, tasting and feeling by skin and mucous layers. The information thus obtained gives the brain and spinal cord the possibility to react adequately. Special structural and spatial organizations in this region are a prerequisite for storing all the organs effectively and let their different functions unharmed. To understand these relations, four main compartments are discerned (Fig. 1.1).

1. The neurocranium: the brain case with skull base, surrounding the brain, and including in its base the ear.
2. The viscerocranium or facial skeleton: the case containing the eye, nose and mouth.
3. The branchial system or primitive, developmental gill-arch system: mouth and nose can be considered extensions of the branchial system. The branchial system mainly makes up the collum of the neck and in it are organs like: pharynx, larynx, and thyroid and thymus glands.
4. The nucha constructed by vertebral column, within it the spinal cord and muscles around it.

The border between neuro- and viscerocranium is sharp: the skull base. At the opposite end, there is a clear overlap between the viscerocranium and the branchial system within the collum's upper part.

The border between collum (neck) and nucha (nape) is sharp and is determined by a fascia (a connective tissue blade): the fascia prevertebralis (layer of the cervical fascia), also called fascia colli profunda, placed just in front of the vertebral column.

These borders are clinically important: any damage below line 1 goes to the oto-rhino-laryngologist, ophthalmologist, or oral-maxillo-facial surgeon, above it is mainly the responsibility of the neurosurgeons. The same holds for line 2: behind it the neurosurgeons, in front of it the other specialists.

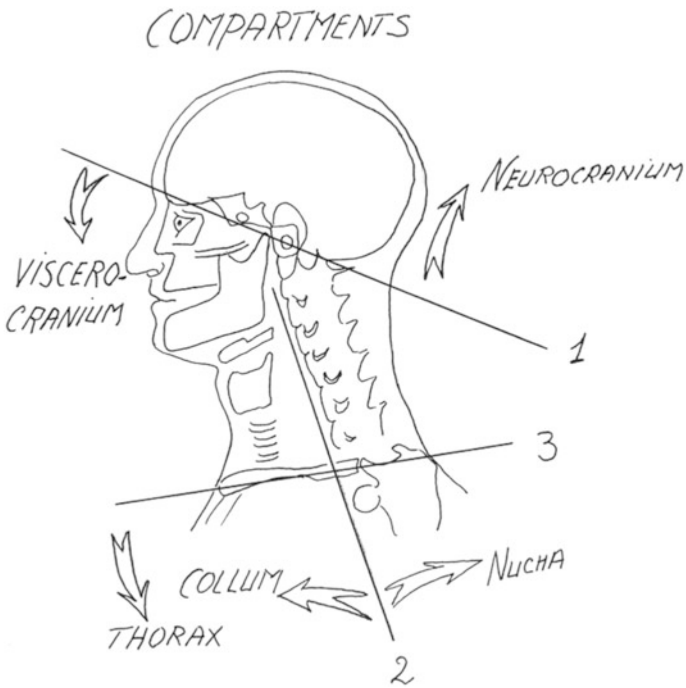

Fig. 1.1 Compartments in Head and Neck: 1 border between neurocranium and viscerocranium (the line between upper orbita border, the superciliary ridge, and ear entrance, meatus acusticus externus, parallels the skull base), 2 border between collum and nucha (the fascia prevertebralis or fascia colli profunda), 3 border between neck and thorax (thorax aperture) © E.Marani

1.2 Spatial and Structural Relations

The human embryo has acquired essential human characteristics by four weeks of gestation. The main developmental features are the four branchial vessel arches and the prosencephalon that has grown ventral of the pharynx. The progress of the facial structures are initiated together with the nasal structures. The interrelations between brainstem, pharynx, branchial arches and heart tube are increased. The relations between the developing eye and its surrounding mesenchyme of nose and face are established. Moreover, the relations of the otic vesicle in the area caudal to the bend of the rhombencephalon are determined. In the following weeks, this key stage is transformed into a creature with a Head and a Neck. Main characteristic of this part of the development is the lateral growth of Head and Neck, with the growing ear in a crucial position. This lateral extension leaves the primary relationships between brainstem, pharynx and skull base unaffected. In this lateral extension, the eyes and maxillary processes form the lateral border of the midregion that is dominated by the nasal structures. The mandible follows this lateral extension. A forward projection in the head region is advanced by the growth of the mandibular arch, the hyoid arch and the cervical sinus. This liberated these structures from the heart area. The widening of the cervical sinus could be seen as the formation of a short neck.

These spatial and structural relations of Head and Neck are indicated in Fig. 1.2:

a. The neurocranium has to encompass the brain, which increased in volume during development, but also underwent temporalization: the cortex curved and moved laterally, producing at maturity a spiralization like in an ammonite. The cerebellum has to stay below the cortex, due to the space-taking process of the brain hemispheres. The ear organ, included in the petrosal bone, part of the temporal bone, had to develop, as a consequence, in between cortex and cerebellum. The eye, as an extension of the central nervous system, had to take its place in front of it.
b. The skull base, also the roof of the orbit, needed to surround the cranial nerves and had to give access to the end of the brainstem in its continuation into the spinal cord. At the transition from the temporal lobe towards the facial bones, a special bony structure, the sphenoid bone, is developed and with its greater wing supports the temporal lobe of the brain. Cerebral veins found their way out of the skull.
c. The mandible had to connect to the skull to allow masticatory movements later in life and contains the muscular bottom of the mouth. Its prominence contributes to the maxillary part of the skull during development (see Section "Coherence Spatial").
d. The maxilla forms the base of the orbit and had to incorporate the nose. The start of the primitive digestive tract (tongue) and airways needed to find their internal and external connections in the viscerocranium. Pharynx and larynx developed their structural relations and needed connections to the skull base for hanging.
e. The muscles, mimic, skeletal and masticator ones, make the face and neck's outer appearance (here are indicated sternocleidomastoid and trapezius muscles that are important for turning and keeping the head upright).

1.3 Paired and Unpaired Structures

Structures present in the midline of Head and Neck are considered unpaired (normally they include an unpaired lumen), although they were generated embryologically as bilateral symmetric structures around it, e.g. pharynx, late development of the nose (see Section "Coherence Spatial"), mouth and larynx. Their bilateral innervation demonstrates overlap. It is therefore understandable that the twelfth cranial nerve (N. Hypoglossus; N XII) can be transplanted one sided, on other malfunctional neural connections, without serious dysfunction of the tongue (Malessy et al. 1999). This does not hold for the arytenoids, they are produced as paired structures. Paired and unpaired are also important in function. Although two temporomandibular joints are present, chewing is an unpaired process, like using the vocal cords by the arytenoids. Structures created in duplicate (eyes) are often partially independent in their function (you can close one eye and still function). To produce an integrated bilaterally functioning system, a complex control system in the nervous system is needed in such cases.

1.4 Coherence Spatial

In Head and Neck, the principle of the "*coherence spatial*" (spatial coherence: Landsmeer 1968) is especially valid. The spaces occupied by structures and organs are not only determined by their own form and function, but also by the form and function of surrounding structures. This principle is a good guide for understanding the development, but is also a good lead into the understanding of the mature Head and Neck. Within this principle, it is clear that some organs are more influential ("more equal") than others, e.g. in the case of the skull base these are: the eye, ear and brain (see Fig. 1.2a, b). If the coherence spatial is disturbed (e.g. by an abnormal development), the defect always has its origin in a shortness of space (encephalo-meningocèle) or abundance of space (hare lip).

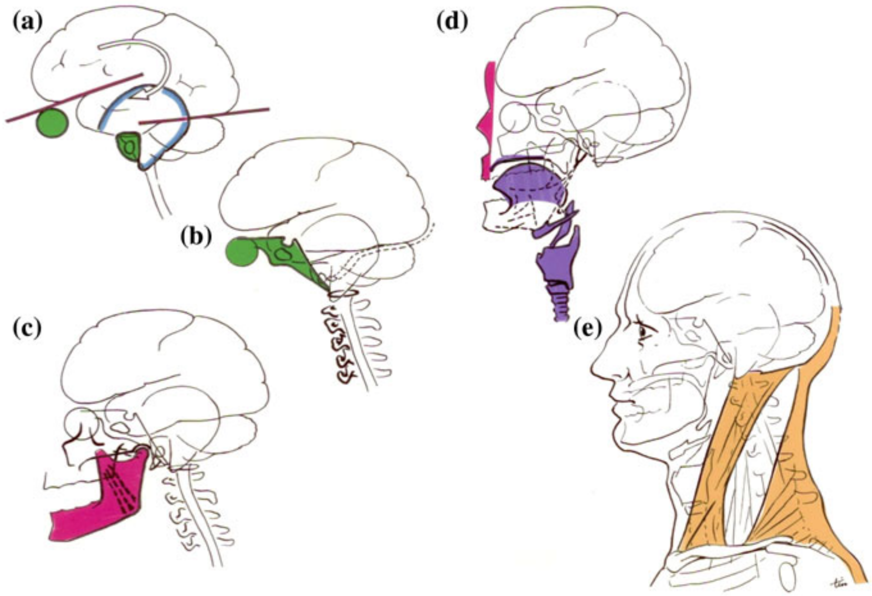

Fig. 1.2 Spatial and structural relations in the Head and Neck area. One should note that although this summation is ordered from a to e, all these spatial and structural relations more or less coincide during development. For explanation, see Section "Spatial and Structural Relations" (changed and adapted from J. M. F. Landsmeer†)

Two examples will be treated here:

The encephalo-meningocèle (also called bifid cranium, cephalocèle or craniocèle) and chordomata are good examples of disturbance of the coherence spatial. Figure 1.3 shows an early embryological stage with three borders, where they can develop in the Head and Neck area:

1. Between future neurocranium and viscerocranium
2. Between collum and nucha
3. Between neck and thorax.

First note that these places coincide with the borders of the compartments as described above. Second, e.g. in border 1, between neurocranium and viscerocranium, the skull base develops. Everywhere within the skull base, the encephalo-meningocèle can originate. These encephalo-meningocèles, by their enlargements, deform other structures below and above the skull base, even to the extent that the skull vault cannot close and brain extends out of the skull (Fig. 1.3).

Thus, in normal situations structures or organs are *mutually dependent*. This dependence is not exclusively regulated by the human genome. The number of codons in the DNA is 10^8 for the entire body, while the brain alone has over 10^{16} connections. Therefore, the growth of the brain also has its own laws. This holds for most organs and structures in Head and Neck. These laws are grouped under the concept “Automation of Development” or “Cell Sociology” (e.g. see Chandebois and Faber 1983).

So, the construction of the spatial relations of the mature Head and Neck from early development till into maturity partially obeys its own laws and of course is also directed by genetics. For a better understanding of the “coherence spatial”, one should notice that:

1. differentiation is producing cellular diversity
2. morphogenesis is organizing different cells into tissue and organs
3. growth is solely the increase in size.

The results of differentiation, morphogenesis and growth are organs that change relations by themselves in the bodily space to other changing organs: “The position of the elements in the process of ontogeny is also significant to their functions” …“The position of elements shifts greatly during ontogeny in order to carry out their activities” … “The specific position for the specific element is essential to carry out certain functions in a particular spatial arrangement” (Dutta 1982) to select just a few sentences from an overview of vertebral form and function discussion that swept through morphology from the 1960 to 1990 (see Dullemeijer 1974).

Processes that are involved in differentiation, morphogenesis and growth are:

– induction,
– fusion,
– cell death: apoptosis and necrosis,